10/519984

PCT Rec'd PCT/PTO 04 JAN 2005

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re patent application of

Martin KASPAR et al.

Corres. to PCT/EP2003/012224

For: HEAT EXCHANGER

VERIFICATION OF A TRANSLATION

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

I, Susan ANTHONY BA, ACIS,

Director of RWS Group Ltd, of Europa House, Marsham Way, Gerrards Cross, Buckinghamshire, England declare:

That the translator responsible for the attached translation is knowledgeable in the German language in which the below identified international application was filed, and that, to the best of RWS Group Ltd knowledge and belief, the English translation of the international application No. PCT/EP2003/012224 is a true, faithful and exact translation of the corresponding German language paper.

I further declare that all the statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful, false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful, false statements may jeopardize the validity of legal decisions of any nature based on them

Date: September 3, 2004

Signature :

Post Office Address :

For and on behalf of RWS Group Ltd
Europa House, Marsham Way,
Gerrards Cross, Buckinghamshire,
England.

10/519984
DT12 Rec'd PCT/PTO 04 JAN 2005

WO 2004/053411

PCT/EP2003/012224

BEHR GmbH & Co. KG
Mauserstraße 3,
70469 Stuttgart

Heat exchanger

The invention relates to a heat exchanger, in particular a condenser or gas cooler for air conditioning systems, in particular for motor vehicles, preferably according to the preamble of patent claim 1.

Condensers have become known from EP-B 0 414 433, in which two condensers are arranged one behind the other on the air side and are connected mechanically to one another by means of additional fastening elements. On the refrigerant side, the flow passes through the two condensers either in series or in parallel. In the case of the series connection, heat exchange takes place in cross countercurrent, that is to say the flow passes first through the leeward-side condenser, and the refrigerant then passes via a connecting line over into the windward-side condenser and flows through the latter as far as the refrigerant outlet located on the windward side. The two condensers have the flow passing through them in a multiflow manner with a decreasing flow cross section (degressive connection). A deflection of the refrigerant therefore takes place only within the plane of each condenser, that is to say only in width. This known duplex condenser has the disadvantage that two condensers have to be connected to one another both mechanically and on the refrigerant side, thus necessitating additional components and assembly time. This means increased production costs. Furthermore, the known condenser also has thermodynamic potentials, since the flow does not pass through it

optimally.

The object of the present invention is to improve a heat exchanger, in particular gas cooler or condenser, of the type initially mentioned, to the effect that, while the end face remains the same, the power output is increased and/or the weight and/or production costs are reduced.

The solution for achieving this object arises from the features of patent claim 1.

The heat exchanger according to the invention, such as, in particular, condenser or gas cooler, is preferably produced as a materially integral block which is preferably soldered "in one shot". Consequently, mechanical connection parts are dispensed with, and production costs are lowered. Furthermore, the condenser is divided in the plane or in the planes of the flow ducts, that is to say in width, into blocks and/or perpendicularly to the planes, that is to say in depth, into segments through which the flow passes in succession, both a deflection in depth or in width and a deflection in depth and in width taking place. Owing to this division of the two-row condenser network, optimum throughflow possibilities arise on the refrigerant side, thus resulting in an increase in the power output of the condenser.

Advantageous refinements of the inventions may be gathered from the subclaims.

Advantageously, there is an even number of segments, since each block consists of two segments with an equal number of flow ducts. Advantageously, however, there may also be an odd number of segments, to be precise when one segment (or else a plurality) is subdivided into subsegments through which the refrigerant flows in

succession. The throughflow possibilities of the condenser are thereby further extended, thus allowing additional increases in power output. It is advantageous, furthermore, if the refrigerant inlet is arranged on a leeward-side or windward-side segment and the refrigerant outlet is arranged on a windward-side or leeward-side segment.

According to an advantageous refinement of the invention, the flow passes through the individual segments in succession, in such a way that a deflection of the refrigerant in depth and in width takes place alternately. This gives rise to a cross counter/cocurrent for heat exchange between air and refrigerant.

According to a further advantageous variant of the invention, after a deflection in depth, a simultaneous deflection in depth and in width takes place. This gives rise, for heat exchange between air and refrigerant, to a cross countercurrent which entails further thermodynamic advantages.

According to an advantageous refinement of the invention, the flow ducts are designed as flat tubes, specifically either in two, three or more rows or in one row, the "continuous" flat tube having the flow passing through it in a two-flow, three-flow or multiflow manner. The flat tubes in this case have, if appropriate, inner ducts which are arranged in parallel and through which the flow passes in parallel. These ducts may also have connecting orifices with respect to one another. These flat tubes may also have turbulence inserts which are introduced into the flat tube.

Furthermore, it is advantageous if the flat tube ends are fastened in a manifold which is common to more than one flat tube and in which the deflection in depth

takes place. Furthermore, in an advantageous solution, the flat tube ends issue on the other side into two manifolds in which the deflection in width takes place. In this case, it is advantageous if the two manifolds either are produced in one piece and consequently hold the block together or are produced as separate manifolds which are held together via the "continuous" flat tubes. Advantageously, the flat tubes have arranged between them continuous corrugated ribs which, by being soldered to the flat tubes, ensure a compact and inherently stable condenser block.

According to a further advantageous refinement of the invention, additional deflection members between the manifolds are provided, by means of which a simultaneous deflection of the refrigerant both in depth and in width becomes possible. By means of these deflection members, for example tube bends, segments through which the flow is capable of passing in series are connected to one another on the refrigerant side. These deflection members may be soldered into the manifolds, so that this variant of the condenser according to the invention can also be soldered in one operation in the soldering furnace.

Exemplary embodiments of the invention are illustrated in the drawing and are described in more detail below. In the drawing:

fig. 1 shows a two-row heat exchanger with deflection in depth and in width,

fig. 2 shows a two-row heat exchanger with deflection in depth and deflection both in width and in depth,

fig. 3 shows two manifolds formed in one piece for two flat tube rows,

fig. 4 shows two separate manifolds for a row of two-flow flat tubes,

fig. 5 shows a first flow variant,

fig. 6 shows a second flow variant,

fig. 7 shows a third flow variant,

fig. 8 shows a fourth flow variant, and

fig. 9 shows a power output graph for a heat exchanger according to the invention, such as a condenser, as compared with the prior art.

Fig. 1 shows a two-row heat exchanger 1, such as a condenser or gas cooler, with a first row 2 and a second row 3 of flat tubes 4, known corrugated ribs, not illustrated, being arranged between the flat tubes 4.

The rib height of the corrugated ribs, that is to say the distance between two flat tubes in a row, is advantageously 4 mm to 12 mm. The rib density, that is to say the number of ribs per decimeter, is advantageously in the range of 45 to 95 ribs/dm, which corresponds to a rib spacing or a rib division of 1.05 to 2.33 mm. The rib or corrugated rib may advantageously be inserted from a strip, in which the strip is inserted in corrugations or in zigzag form between the flat tubes. Expediently, the rib thus configured will have thermal separation between different regions, so that the regions which are arranged between different flat tubes or flat tube regions are at least partially insulated thermally.

In a further advantageous embodiment, the rib may also

consist of a plurality of individual strips which are inserted between the adjacent flat tubes. It is advantageous, in this case, that the individual ribs of different rows have no thermal connection.

The flat tubes are advantageously configured in such a way that the tube width, that is to say the extent of the tubes in the direction of an adjacent tube of the same planes, is in the range of 1 mm to 5 mm, in particular advantageously of 1.2 mm to 3 mm. The extent of the tubes between the direction perpendicular to the planes, the tube depth, is expediently in the range of 3 mm to 20 mm, advantageously in the range of 5 mm to 10 mm.

In one exemplary embodiment of the invention, the tube depth may be essentially identical in the blocks of the heat exchanger. In another exemplary embodiment of the invention, however, the selected tube depth may also be different from block to block. It is particularly expedient if the tube depth in the windward-side plane is smaller than the tube depth in the leeward-side plane.

In the heat exchangers illustrated in the figures, the tubes of different planes are arranged in alignment in series, as seen in the airflow direction, that is to say they are arranged in series of the same height.

In heat exchangers that are not illustrated, the tubes of one plane may be arranged so as to be offset with respect to the tubes of a further plane. This offset arrangement may preferably take place up to the height of half the rib height plus half the tube width. Intermediate values may also be assumed. In such an exemplary embodiment, different or identical ribs, which are advantageously produced as independent strips, may be used between the tubes of various

planes.

The flat tubes 4 of the two rows 2, 3 have flat tube ends 4a which issue into a common manifold 5. On the other side, the flat tubes 4 of the two rows 2, 3 have flat tube ends 4b which issue into two separate manifolds 6, 7. The manifold 7 is a refrigerant inlet 8. The two manifolds 6, 7 are subdivided into manifold sections by means of partitions, of which a partition 9 is illustrated only in the manifold 6 which is illustrated as being open. The air flows through the condenser in the direction of the arrow L, the airflow direction. The flow profile of the refrigerant in the condenser 1 is illustrated by a multiply angled line beginning with the refrigerant inlet KME and ending with the refrigerant outlet KMA. As is explained in more detail later, the two rows 2, 3 of the flat tubes 4 are subdivided into three blocks I, II, III, each block being subdivided in each case into two segments Ia, Ib; IIa, IIb and IIIa, IIIb. The refrigerant therefore flows first through the leeward-side segment Ia of the rear tube row 3, then passes into the manifold 5, where it is deflected in depth, illustrated by the arrow UT1, and then passes into the windward-side segment Ib and into the windward-side manifold 6, where it is deflected in width, illustrated by the arrow UB1. The refrigerant then flows through the next segment IIa back again into the manifold 5, where it is deflected once more in depth, but in the opposite direction to previously, according to the arrow UT2. It flows thereafter through the leeward-side segment IIb into the leeward-side manifold 7, is deflected there once more in width, illustrated by the arrow UB2, flows again through a further segment IIIa into the manifold 5, is again deflected there in depth, illustrated by the arrow UT3, and finally flows through a last windward-side segment IIIb to the refrigerant outlet KMA. As a result of this throughflow of refrigerant, on

the one hand, and of air, on the other hand, a cross counter/cocurrent is obtained, specifically because, on the one hand, the refrigerant and the air run in cross current and, on the other hand, the deflections in depth UT1, UT3 run opposite to the airflow direction L and the deflection in depth UT2 runs in the airflow direction.

Fig. 2 shows a further exemplary embodiment of a condenser 10 which is constructed essentially identically to the condenser 1 according to fig. 1, the same reference numerals being used for identical parts. In contrast to the exemplary embodiment according to fig. 1, the condenser 10 has an additional partition 11 in the windward-side manifold 6 and two tubular deflection members 12, 13 which in each case connect sections of the windward-side manifold 6 to sections of the leeward-side manifold 7. The refrigerant flow path is again illustrated by a continuous multiply angled line beginning at the refrigerant inlet KME and ending at the refrigerant outlet KMA. The refrigerant thus flows first through the leeward-side segment Ia, is deflected in the manifold 5 in depth in the direction of the windward-side segment Ib according to the arrow UT1 and flows through the latter until it reaches the windward-side manifold 6. Due to the position of the partition 11, there are therefore six flat tubes 4 for the segments Ia and Ib of the block I. The refrigerant is then deflected via the deflection member 12 into a section of the leeward-side manifold 7, that is to say a simultaneous deflection both in width and in depth takes place, as illustrated by the arrow UBT1. After this deflection, the refrigerant flows through the leeward-side segment IIb in the direction of the manifold 5, is deflected there opposite to the airflow direction according to the arrow UT2 and enters the windward-side segment IIa. After the windward-side manifold 6, that is to say the section between the two

partitions 9, 11, is reached, a renewed deflection in width and in depth takes place by means of the deflection member 13, this being illustrated by the arrow UBT2. Finally, the refrigerant flows through a further leeward-side segment IIIa, is once again deflected in the manifold 5 according to the arrow UT3 and finally flows through the last windward-side segment IIIb as far as the refrigerant outlet KMA. This flow pattern is a cross countercurrent, because the deflection in depth UT1, UT2, UT3 takes place in each case opposite to the airflow direction L. This variant has thermodynamic advantages, as compared with the variant according to fig. 1.

Fig. 3 shows the design of the two manifolds 6, 7, referred to here by 6′, 7′, in the form of a double tube 14 of spectacle shape. The two manifolds 6′, 7′ are formed from a continuous sheet metal strip 15 with end edges 16, 17 which are inserted into a web 18 connecting the two manifolds 6′, 7′ and are soldered to said web. This results in a firm connection between the two manifolds 6′, 7′ which receive the flat tubes 4 with their flat tube ends 4b. This makes it possible to produce the two-row condenser in a soldered block.

Fig. 4 shows a further version for the design of the manifolds 6, 7, referred to here by 6″, 7″, which are designed as separate manifolds. The flat tubes here are not arranged in two separate rows, as in the previous exemplary embodiments, but are formed by one "continuous" flat tube 19 through which the flow passes in a two-flow manner, that is to say in a front (windward-side) region 19a and a rear (leeward-side) region 19b. The two regions 19a, 19b are separated from one another in flow terms by means of a middle separation region 19c. The continuous flat tube 19 has separate flat tube ends 19a′ and 19b′ which are inserted into rim holes 20 for the two manifolds 6″, 7″

and are soldered to these. An interconnected compact soldered condenser block is likewise obtained in this way.

Fig. 5 shows a diagrammatic illustration of the flow pattern of the exemplary embodiment according to fig. 1, that is to say a cross counter/cocurrent. The entire network of the condenser 1 according to fig. 1 is subdivided into three blocks I, II, III, each block consisting of two segments Ia and Ib, IIa and IIb and IIIa and IIIb. The segments of a block have in each case the same number of tubes and lie in series, as seen in the airflow direction L. In the exemplary embodiment according to fig. 5, the segments Ia, Ib have in each case nine flat tubes 4, the segments Ia, Ib have in each case seven flat tubes and the segments IIIa, IIIb have in each case five flat tubes 4. This results on the refrigerant side in a degressive connection, that is to say the refrigerant-side outlet cross section is smaller than the refrigerant inlet cross section and amounts to 5/9 or to 56 percent of the inlet cross section. This is a favorable value for the gradation of the refrigerant-side flow ducts in the case of three blocks and six segments. Remaining alphanumeric designations correspond to those of the exemplary embodiment according to fig. 1, that is to say the flow profile has three deflections in depth UT1, UT2 and UT3 and two deflections in width UB1 and UB2.

Fig. 6 shows the flow pattern on which the exemplary embodiment according to fig. 2 is based, once again the same alphanumeric designations being adopted. The network of the condenser 10 (fig. 2) is again subdivided in width into three blocks I, II and III, and each block is subdivided in depth into two identical segments Ia, Ib; IIa, IIb and IIIa, IIIb. The number of tubes for the block I is 2× nine, for the

block II is 2× seven and for the block III is 2× five, that is to say as in the previous exemplary embodiment. In the same segments, in each case, the deflection in depth takes place in the same direction, that is to say opposite to the airflow direction L, in the direction of the arrows UT1, UT2 and UT3. Moreover, from the segments Ib to the segment IIb, a deflection both in width and in depth takes place, as illustrated by the arrow UBT1, and, from the segment IIa to the segment IIIa, a deflection both in width and in depth likewise takes place, as illustrated by the arrow UBT2. This flow type is to that extent a cross countercurrent which affords advantages in power output terms, as compared with the cross counter/cocurrent.

Fig. 7 shows a further flow pattern in which the network of the condenser is divided in width into two blocks I, II. The block I is subdivided in depth into two identical segments Ia and Ib which in each case have nine flat tubes 4. The block II is subdivided into a segment IIb with nine flat tubes 4 and two subsegments IIaa with five flat tubes 4 and one subsegment IIab with four flat tubes. The refrigerant first flows through the leeward-side segment Ia, a deflection in depth then takes place according to the arrow UT1, the refrigerant subsequently flows through the windward-side segment Ib, a deflection in width, according to the arrow UB1, thereafter takes place into the adjacent subsegment IIaa, there is then a deflection in depth UT2 to the leeward-side segment IIb, and there is again a deflection in depth, according to the arrow UT3, from there to the windward-side subsegment IIab. Owing to the subdivision of one segment into two subsegments, five flow paths are obtained here, that is to say an odd number. Such a variant with subsegments may be advantageous, in particular, for the subcooling of the refrigerant in the last subsegment IIab.

When the division of a segment into subsegments is employed, a partition is advantageously used in the manifold. This partition may expediently be designed as a separating plate.

Fig. 8 shows a further variant of the division of the condenser network into seven flow paths. The network is subdivided in width into three blocks I, II, III; the block I is subdivided into two identical segments Ia, Ib, each with nine flat tubes 4. The block II is subdivided into two identical segments IIa, IIb, each with seven flat tubes, and the block III is subdivided into one segment IIIa with seven flat tubes and two subsegments IIIba with four flat tubes and one further subsegment IIIbb with three flat tubes. The refrigerant routing between said segments takes place in the order of the arrows designated below: UT1, UB1, UT2, UB2, UT3 and UB3.

All the variants described above (flow patterns with a degressive connection) achieves the largest power output when the ratio of the refrigerant outlet cross section to the refrigerant inlet cross section is in the range of 0.25 to 0.40. This ratio corresponds to the number ni of flat tubes of the last throughflow segment to the number n1 of flat tubes of the first throughflow segment (presupposing identical flat tube cross sections).

Fig. 9 shows a power output comparison of the condensers according to the invention with the prior art, with a variable air onflow velocity in m/s on the abscissa. The power output of the condenser in kW is plotted on the ordinate. The unbroken line S represents the power output of a conventional serpentine condenser with multiflow throughflow and with degressive connection. The first variant of the invention

according to fig. 1 is illustrated as a closely dotted line and is identified by KGG, which stands for cross counter/cocurrent. The second variant of the invention according to fig. 2 is illustrated as a widely dotted line and is designated by KG, which stands for cross countercurrent. It can be seen that the two inventive variants lie well above the prior art in terms of power output, the variant 2 being superior to the variant 1 at higher air velocities. This results in a marked advantage in favor of the inventive division of the condenser network into blocks and segments with deflection in depth. The illustrated curves S, KGG, KG are derived from calculations for condensers with an identical end face and with an identical rib density.

According to a further inventive idea, the flow can pass through the heat exchanger from the top downward or from the bottom upward. Bottom and top are defined by the installation position of the heat exchanger. Also, for example, a flow can pass through one plane of the heat exchanger from the bottom upward and through another plane from the top downward. In this case, the flow ducts are preferably arranged horizontally.

In a further advantageous exemplary embodiment, the flow ducts are expediently oriented vertically and the manifolds are oriented horizontally.